THE INSTITUTE OF PHYSICS

BULLETIN

CONTENTS

Scientific Uses of Digital Computers . . L. Fox **185**

Some Aspects of the International Geophysical Year Colin A. Ronan **189**

Physics in the Australian Defence Scientific Service **193**

Reviews of Books **199**

Branch News **204**

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

UNIVERSITY OF AUCKLAND
New Zealand

SENIOR LECTURESHIP IN PHYSICS

Applications are invited for the above post. Preference would be given, other things being equal, to candidates with theoretical or experimental knowledge of any of the fields: angular correlation of nuclear radiations: polarized nuclear reactions; ion optics; time-of-flight of neutrons or similar fields, combined with special qualifications as a lecturer in either (*a*) nuclear physics (theoretical or experimental) or (*b*) advanced electricity and magnetism. The salary scale is £1,315 per annum, rising to £1,615 per annum by three annual increments. Commencing salary within this scale will be determined according to qualifications and experience. In the case of a person appointed from overseas, salary will be paid as from date of sailing. An allowance is made towards travelling expenses. Further particulars and information as to method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in New Zealand and London on August 24, 1959.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY
Solid State Research

A few research bursaries exist for PHYSICISTS, CHEMISTS or METALLURGISTS with good honours degrees for higher degree work on (*a*) deformation characteristics of ceramics, (*b*) properties of oxide films, (*c*) structure of liquid alloys, (*d*) transmission electron microscopy. Minimum value £400 per annum plus fees.
Applications to Professor J. G. Ball, Metallurgy Department, Imperial College, London, S.W.7.

UNIVERSITY OF AUCKLAND
New Zealand

Applications are invited for the following vacancies for the 1960 Session :— LECTURESHIPS in mathematics, physics (one or more). The salary scale for a Lecturer is £1,025 - £1,275 p.a. Commencing salary will, in each case, be determined according to qualifications and experience. In the case of overseas appointees, payment of salary will commence as from date of sailing. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in New Zealand and London, on August 15, 1959.

LONDON COUNTY COUNCIL
SCIENTIFIC BRANCH

PHYSICIST required for research work at County Hall on properties of materials and in field of health physics. Honours degree in physics required. General physical experience and knowledge of radio-chemical equipment desirable. £740–£1,535 commencing according to qualifications and experience. Apply Medical Officer of Health (D.1/A), County Hall, S.E.1, by August 29, 1959.

UNIVERSITY OF CAPE TOWN
South Africa

SENIOR LECTURESHIP IN NUCLEAR PHYSICS

Applications are invited for the above post. The salary scale is £1,760 × £60–£2,060 per annum. The duties of the senior lecturer will include teaching and laboratory supervision of students and some examining and organizing of courses. He will be expected to train advanced students in nuclear physics and should himself be interested in nuclear research. Application (with copies of testimonials) should state age, qualifications, experience and research work completed or in progress and give the names of two referees whom the University may consult.
Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and further information about the work of the department should be obtained) not later than September 1, 1959. An additional copy should be sent direct by airmail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date. The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

THE ELECTRICAL RESEARCH ASSOCIATION has a vacancy for a GRADUATE on the research staff of the Rural Electrification Section, to work on problems concerning the applications of electricity in horticulture. He should possess a good degree in physics with some knowledge of electronics and should be capable of designing original equipment and preparing technical reports. Previous research experience would be an advantage. Starting salary will be in the range of approximately £700-£900 according to qualifications and the post is superannuable under the F.S.S.U. Applications should be addressed to the Head of the Rural Electrification Section, E.R.A. Field Station, Shinfield Green, Near Reading, Berkshire.

ENGINEERS and PHYSICISTS are required for an Electronic Application Laboratory in the Portsmouth area. They will be required to work on new techniques in miniaturization and the design of equipment for use in extreme environments. Applicants should be well qualified and have several years' experience in the design and analysis of circuitry using valves and/or transistors. A good appearance and personality is desired as the work will involve customer liaison. Positions are also available for junior engineers and assistants with good chances of promotion. Salary according to age, qualifications and experience. Pension and Life Assurance Scheme. Housing assistance. Car allowance if appropriate. Full particulars to Personnel Manager, Leigh Electronic Developments, Ltd., New Lane, Havant, Hants.

UNIVERSITY OF CANTERBURY
Christchurch, New Zealand

LECTURESHIP IN PHYSICS

Applications are invited for the above position. It is hoped to appoint someone who is prepared to work in the field of the solid state, but applications will be considered from persons with experience and interest in other fields. The salary will be at the rate of £1,025 per annum, rising by annual increments of £50 to £1,275 per annum. Commencing salary will be in accordance with qualifications and experience and an allowance will be made towards travelling expenses. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in New Zealand and London on September 30, 1959.

UNICAM INSTRUMENTS LTD.

Vacancies exist for SCIENTISTS AND TECHNICIANS in the Technical Liaison Department of a leading scientific instrument company. These responsible posts will involve the setting up of a laboratory initially for the special testing of infra-red and ultraviolet spectrophotometers and later for new analytical instruments arising from the company's development program. Full training will be given and, since the Department is an expanding one with a wide range of responsibilities, opportunities exist for progress. Attractive salaries, fully consistent with age and experience, will be paid, working conditions are good and a pension scheme in operation. For further details please write to Head of the Technical Liaison Department, Unicam Instruments, Arbury Road, Cambridge, quoting ref. N.A. 7.

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Scientific Uses of Digital Computers*

By L. FOX, M.A., D.Phil.

(*Director, University of Oxford Computing Laboratory*)

INTRODUCTION

In discussing the scientific applications of digital computers it is not sufficient, or even meaningful, to say that the computer can solve problems for firm *X*, or research department *Y*, though it is tempting to do so. A more sensible statement would be that the computer can solve problems in stress analysis, for example, but even this needs qualification. The truth is that the question, "Can your machine solve my problem ?", can be answered only when the problem has been set in mathematical terms.

The answer may be "Yes," because it is identical in kind with other problems which have been solved, or "No," because the programming is prohibitive, or the actual machine time is more than can be spared (or perhaps paid for !), or because there is no known method which might have even a possibility of success. Finally there is the Gallup "I don't know," in cases in which various methods might possibly but not certainly be expected to work.

As examples of these answers consider the solution of simultaneous algebraic equations. If they are linear, of a reasonable number, containing coefficients with not too many figures, and whose answers are required with not too great precision, we shall be able to give an unqualified affirmative. On the other hand a very large number of linear equations, with no special properties, may represent a prohibitive task. Using the Ferranti Mercury, for example, which we have at Oxford University, the time taken to read in the data for one thousand such equations, with say nine-figure coefficients, would take 20 hours, the computation would last about a week, and the cost is of the order of £50 per hour ! The allied problem of inverting a matrix of this size would use about three weeks computing time, in addition to about a week in which the machine is punching results, usable in this period for no other purpose. The printing of results, to get them in intelligible form, would take a further month with our present teleprinting equipment. If the simultaneous equations are non-linear we are not certain of a workable method, though if fairly close approximations to the answers were known in advance we have some possibility of success.

Other problems arise if results are needed with great precision, which may necessitate the use of multi-length arithmetical operations, increasing our computing time by a factor which might be quite large.

In short, we are limited in technique, and the machines are limited in speed and size. Both limitations tend to decrease with time, but the size and complexity of the work we are asked to do is correspondingly increasing !

SCIENTIFIC PROBLEMS NUMERICAL ANALYSIS PROGRAMMING

I separate scientific problems from other types, for example commercial applications, with the idea that, though the data and results may be voluminous, the computing time is a large part of the whole. This is not the case, for example, with pay-roll calculations, in which the computing time is usually trivial. Scientific problems may also involve difficult mathematics and elaborate numerical techniques, whereas a schoolboy might easily understand the arithmetic of commerce.

Before we can use our machine it is, however, essential to turn our mathematical and numerical operations into those which the machine can perform. Basically this is limited to the single operation of addition of two numbers, which is easily extended to subtraction, multiplication, and division. Other machine operations, such as transfers, jumps, logical operations and the like, are effectively valuable in making programming easier. The point is that we cannot ask the machine to differentiate a mathematical expression, evaluate an integral, or give an analytical solution to a differential equation.

The technique of turning a given physical problem into mathematical terms, and then into an ordered sequence of numerical operations, belongs to the field of Numerical Analysis, and is largely independent of the type of computing equipment at our disposal. The operation of turning this into a "flow diagram," a diagrammatic description of the list of operations, is also mainly independent of the machine, but the last operation, the writing of our program in machine language, requires, of course, a knowledge of the particular machine which we are going to use.

* A lecture to the South Wales Branch of the Institute, given in Cardiff on February 13, 1959

In scientific work the numerical analysis aspect is very important. A bad method, however well " coded " in machine language, is completely useless. A good method inefficiently coded is less serious, involving only a waste of machine time. The ideal, of course, is to have a good method well programmed and coded.

Consider, for example, the use of a recurrence relation, such as

$$J_{n+1}(x) - (2n/x)\, J_n(x) + J_{n-1}(x) = 0, \qquad (1)$$

from which we can in theory determine values of the Bessel function $J_n(x)$ for fixed x and increasing integer values of n, assuming a knowledge of $J_0(x)$ and $J_1(x)$. In practice we work with a fixed number of figures, the " word-length " of the machine, and our results will be good for values of n less than x, after which they will suffer a rapid loss in accuracy. The shock might be lessened and postponed by working with double-length arithmetic, but the real need is for a different method.

THE PROBLEMS OF NUMERICAL ANALYSIS

I turn now to consider the types of problem which can be tackled, starting in this section with the mathematics, and bringing in later some physical problems which are expressible in the various categories.

It is convenient to separate problems into two main classes, the evaluation of formulae and the inverse process of finding solutions of equations.

Evaluation of Formulae

This class includes all calculations such as the evaluation of $f(x, y, \ldots)$, for different combinations of the parameters $x, y, \ldots$, and different forms of the function f. The function may be algebraic, or involve the elementary functions, or the higher functions of mathematics. It may involve differentiation, or definite integration, or any combination of all these things. In this category I include also direct operations with matrices, such as addition and multiplication, and the evaluation of a determinant.

Solution of Equations

This class includes :

(i) the solution of simultaneous linear equations, inversion of matrices, determination of latent roots and vectors of matrices,

(ii) determination of the zeros of polynomials or of any function of one or more variables,

(iii) the solution of ordinary differential equations, partial differential equations, integral equations, and integro-differential equations.

The two categories are not water-tight. For example, it is quite common to find that the best way of evaluating a function is to solve an equation for it. Calculation of the function

$$f(x, y) = \int_0^\infty \frac{e^{-t}\{J_o(tx)\cosh ty - 1\}}{\sinh t}\, dt, \qquad (2)$$

for example, for a range of x and y covering a closed region in the (x, y) plane, might conveniently be replaced by the solution of the partial differential equation

$$\frac{\partial^2 f}{\partial x^2} + \frac{1}{x}\frac{\partial f}{\partial x} + \frac{\partial^2 f}{\partial y^2} = 0. \qquad (3)$$

Similarly, a common method of finding a real zero of a polynomial is to evaluate the polynomial for selected values of the argument, and to proceed more or less systematically until we find an argument for which the polynomial vanishes. The numerical analyst is constantly seeking such simplifications.

The second category is clearly larger, more interesting, and demands more mathematical and computational skill than the first. Indeed beginners in the field would quite likely make a reasonable shot at problems of the first kind, whereas great experience is often required in the second. I need hardly mention the parts of a university mathematical syllabus which the numerical analyst should know, but he will certainly need more, including for example the theory and practice of finite differences, than he will find at most universities. There are, happily, signs of a welcome change in this direction !

PHYSICAL PROBLEMS IN THE FIRST CATEGORY

Turning now to physical applications, I look first at some important problems which involve the evaluation of formulae.

Crystallography. This important problem aims at the determination of the arrangement in space of atoms of crystalline structures, to help explain and predict the behaviour of materials used in engineering, the textile industry, medicine, and so on. A typical calculation could require the evaluation of a function

$$F(x, y, z) = \sum_{i=0}^{\infty}\sum_{j=0}^{\infty}\sum_{k=0}^{\infty} F_{ijk}\cos 2\pi\,(ix + jy + kz), \qquad (4)$$

for very many combinations of x, y and z, not uncommonly of the order of 50,000. The infinite sums are replaced by finite sums, but we may have anything between five and one hundred terms in each sum. Problems of this kind, and others similar but more complicated, may take about six months to solve by a combination of punched-card and desk calculating machines. Modern electronic machines do the job in a few hours.

Table-making. The compilation of accurate tables of mathematical functions is a somewhat elaborate task, needing a professional touch in matters of arrangement, choice of material, and checking, as well as in the computational part. Dr. J. C. P. Miller has estimated that most of the tables in the British Association and Royal Society series could have been produced in a few hours, with a very few master programs, with the use of electronic computers.

Tables of this kind will probably be produced less frequently in the future, but practical tables, such as those in the Nautical and Air Almanacs, and perhaps even those which decide how much income tax we pay, are likely to be needed for some time, and their calculation is facilitated very considerably by our modern equipment.

Nuclear physics. Problems in emission and radiation and the determination of electron density frequently lead to the evaluation of multiple integrals. Finite differences are somewhat useless for this purpose, and there is an increasing tendency to use the so-called Monte-Carlo technique, which effectively evaluates the integrand at very many points, distributed randomly in the field of integration, and obtains a weighted average

of these results as an estimate of the integral. The rapidity of machine evaluation, and its patience and lack of fatigue in performing the same type of calculation thousands of times, brings this technique well into the field of possible and valuable methods. It is one of those cases in which the electronic method would hardly be considered feasible with a desk machine.

Design problems. I suppose that most design problems, that is the determination of critical values of various physical quantities defining the physical system, are solved by calculating the effects of a particular design and repeating the calculation with different values of the parameters until the optimum solution is reached.

The design of optical systems, for example, requires the tracing of selected rays of light through a configuration of lenses. In a perfect system all rays which leave a given point in the object plane are required to meet at a point in the image plane. Calculations are simple, based on Snell's law of refraction, but there is a lot of calculation in systems in which there are, not uncommonly, some twenty surfaces. A skew ray may require about twenty minutes computation by desk machine, whereas a complete analysis can be performed in seconds on a high-speed computer.

Road design is another problem of this kind, with more complicated calculation. A road may be composed of three layers of different materials, with different thicknesses h, moduli of elasticity E, and Poisson's ratio σ. The bottom layer is effectively unlimited in depth, and we require to find the stress distribution resulting from uniform pressure applied over a circular area of radius a in the top surface, with a view to choosing an arrangement which gives a good road as cheaply as possible. The general stress distribution is difficult to find, and involves the numerical solution of a somewhat complicated partial differential equation. There are, however, analytical expressions for the solution along the vertical axis of symmetry, in the form

$$\text{“ stress ” } = \int_0^\infty f(x)\, dx. \tag{5}$$

in which all the parameters appear, and the integrand also involves Bessel functions and a number of exponential terms. A single program could be written which would produce all the results required in a few hours. The original work, by desk machine, took several man-months !

PHYSICAL PROBLEMS IN THE SECOND CATEGORY

Problems involving the solution of equations turn up in all scientific fields, and I can mention only a few. First we have the algebraic problems, representing engineering structures with a finite number of degrees of freedom. In addition to standard problems of stress analysis we may need to determine critical configurations. Bridges, for example, should not collapse because of resonance, and the problem reduces to the solution for x and λ of the matrix equation

$$Ax = \lambda x. \tag{6}$$

This is the kind of problem which computers, and recent advances in technique, have made almost trivial. Matrices of order eighty can be treated in less time than hand-computation can cope with order six.

We may go on from here to the “ flutter ” problem, the tendency for aircraft or bridges, at certain air-speeds or wind-speeds, to develop uncontrolled vibrations and to fall apart. The calculation has three stages. First, we determine the normal modes of vibration from an equation like (6), then find from the results the elements of a determinant, the “ flutter ” determinant, and finally determine the critical air speed, a parameter in the coefficients, for which the determinant vanishes, a situation giving rise to undamped oscillations. This critical speed, of course, must be considerably greater than that which the aircraft can achieve. You may remember that comparatively recently a bridge in America disintegrated in a thirty m.p.h. gale, and this has been traced to “ flutter.”

The continuous case, involving differential equations, turns up in astronomy, in which systems of ordinary differential equations describe the motions of planets, sputniks, and guided missiles. In the last of these random elements, so-called “ noise ” or “ jitter,” are often introduced, and the fact that the intermediate calculations are not inspected avoids insomnia for the skilled hand-computer properly trained in numerical analysis !

Other problems involving ordinary differential equations with which I have been involved include an attempt by Sir Edward Bullard to analyse the magnetic behaviour of the earth, resulting in the solution of about twelve simultaneous second-order equations containing a parameter which had many critical values of which we wanted the smallest positive result, and the design of landing gear for aircraft carriers which required the solution of about twenty simultaneous second-order equations with discontinuous coefficients. Such problems would be prohibitive without electronic aids.

Turning now to partial differential equations, we have the so-called “ parabolic ” equations, represented in simplest form by the equation

$$\frac{\partial^2 f}{\partial x^2} = \frac{\partial f}{\partial t}, \tag{7}$$

and which are involved in problems of heat transfer and in diffusion, with applications in medicine, the textile industry, and many other fields. Non-linear equations of this kind also arise in certain aggressive aspects of nuclear physics. It is fair to say that this type of problem, in one space-dimension, is fairly easy by high-speed methods, and problems in more dimensions merely occupy more machine time.

Research is still needed, however, for other types of partial differential equation. The elliptic type, for example, illustrated in its simplest form by Poisson's equation

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} = g\,(x, y), \tag{8}$$

in rectangular Cartesian co-ordinates, turns up in engineering, in the analysis of torsional and flexural stresses in beams and plates, in hydrodynamics, in the flow of incompressible fluids, and in more complicated

forms in viscous fluid flow. We may also need to determine critical parameters, in problems of buckling or of vibration. Some methods are available for problems of simple forms, but non-linearities in the equation or in the boundary conditions, and the possible complicated nature of the shape of the boundary, have so far prohibited the writing of general programs, most problems being tackled on an *ad hoc* basis.

Hyperbolic equations, of which the simplest example is given by

$$\frac{\partial^2 f}{\partial x^2} - \frac{\partial^2 f}{\partial y^2} = 0, \qquad (9)$$

occur in wave motion, in supersonic fluid flow, in the presence of " shock waves," in the motion of tidal flow in rivers, and a variety of other contexts. Non-linearities have smaller disagreeable effect than in elliptic equations, because the method of solution is essentially of the step-by-step variety, a process of " integrating along characteristics." The solution of elliptic equations, on the other hand, involves simultaneous algebraic equations which, as I mentioned earlier, may cause difficulties in the non-linear case.

An interesting problem involving partial differential equations is that of weather forecasting. The Meteorological Office at Dunstable keep a Mercury computer occupied with the solution of two simultaneous non-linear equations in two independent space variables and one time variable. The method of solution is simultaneous in space, step-by-step in time, and at each time step the machine produces estimates of pressure, etc., at points on a grid covering a large part of the Atlantic, in conformity with assumed " models " of the atmosphere. Research is in progress both on improving techniques, including the computation of more reliable initial data from which the step-by-step method begins, and also on more realistic atmospheric models. For such work, of course, a fast machine is essential, since we could hardly be grateful for a twenty-four hour weather forecast which is not available for several days !

Finally, in this class, I may mention some problems in nuclear scattering, which involve solutions of integro-differential equations of the form

$$\frac{d^2 f}{dr^2} + g(r) f = \int K(r, r') f(r') dr', \qquad (10)$$

in which the unknown function appears both differentiated and integrated. In most problems of this type the calculation of the kernel $K(r, r')$ is itself a formidable task, but these problems have been solved successfully by electronic machine.

Then there are problems of the semi-scientific kind, in which both data and computing may be comparable in machine time. They include, for example, many statistical applications such as the fitting of simple curves to sets of observed readings, the so-called regression analysis, and other such problems arising in experimental design and other contexts.

In the same category, though perhaps more scientific according to my original definition, comes the problem of " linear programming," involving mathematically the solution of simultaneous algebraic equations subject to linear inequalities, with the aim of minimizing the cost of complicated operations say in transport or in the proper organization of a large factory. This is a relatively new field which has already achieved spectacular results.

PROGRAMMING

In conclusion I must say a few words about programming. In the early days of electronic machines most programs were compiled by professional programmers, whose skill provided the basic routines from which many other programs can be assembled. These professionals are also providing simpler methods of coding which require much less effort to master by those scientists who cannot afford the time necessary to achieve this expert and detailed knowledge. An example of this is the Autocode for Mercury, developed by Dr. Brooker and other collaborators at Manchester University. This seems to me an important development, and as machines become larger and faster I can envisage the time when the majority of problems can be solved by assembling, with a few easy instructions, those " library " routines which are involved in the solution. Like modern methods of producing food, we may get our results " untouched by hand."

THE INSTITUTE'S JOURNALS

The publication of the *Journal of Scientific Instruments* and the *British Journal of Applied Physics* is affected by the dispute in the printing industry; the July and subsequent issues cannot be issued until the dispute is settled.

The *Bulletin* is printed by a firm not so far affected by the dispute and it should therefore be published as usual although the number may be slightly reduced.

Vol. 10, August, 1959

Some Aspects of the International Geophysical Year*

By COLIN A. RONAN, M.Sc., F.R.A.S.
(*Secretariat of the Royal Society*)

THE International Geophysical Year has, with good reason, been termed " a great scientific adventure". It has been an adventure into many scientific fields and much of the work which was so successful during the official eighteen months of the " Year " is still to continue. I want particularly to comment on certain astronomical aspects of the observational program—indeed such specialization as I can claim must of necessity limit my remarks in this way—and then to give some *personal* opinions on what seem particularly significant educational aspects which the I.G.Y. throws up. Moreover, to concentrate a little on the astronomical side of the I.G.Y. may do no harm, for it is full of interest and, when all is said and done, the sun has been the guiding physical factor behind the observations—the Special World Intervals were triggered off when unusual solar activity occurred—and for long solar study has been the province of the astronomer.

Details of solar activity have been studied ever since the seventeenth century when Galileo turned the newly invented telescope to the sun and discovered, *mirabile dictu*, that the disk was marred by dark spots which came and went. Further investigation showed that the quantity of sunspots varied in a cyclic way, maximum numbers appearing every eleven years. In the centuries following, investigators were able to discern other factors about the distribution of the spots in the sun's disk from cycle to cycle and their general behaviour during the periods of activity. However, the physical nature of the sun remained somewhat of a mystery. Astronomers knew that it was hot but as late as the nineteenth century Sir John Herschel was postulating the existence of living creatures below the hot observable photosphere ! Total eclipses of the sun were carefully observed for these gave the astronomer opportunity to learn something of the thin pearly coloured outer gaseous envelope known, appropriately, as the corona.

By the twentieth century new and powerful techniques have been developed and became much used in solar physics. The first was, of course, the photographic plate which provided a means of quickly and accurately recording in a permanent way the positions of spots and measures of their respective areas. Secondly the spectroscope and spectrograph put great powers of analysis into the hands of the astronomer. Using these devices he could examine the gaseous material of the sun in both qualitative and quantitative ways and, by detailed study of the lines, gain some insight into the magnetic fields associated with the spots themselves. He was also able to disprove the suggestions of Sir John Herschel on the habitability of the sun ! Moreover during the brief periods of total solar eclipse, pink coloured appendages had been observed from time to time and for many years it was not clear whether these were part of the sun or the moon. The spectroscope showed them to be masses of glowing hydrogen gas and it was also found that by widening the slit and observing on the solar limb, these prominences, as they came to be called, could be observed even when no solar eclipse was occurring. An extension of this method was used in the spectrohelioscope and spectroheliograph in which two slits were used, the first in the customary manner and the second to isolate a particular spectral line—a vibration of both slits or what, in fact, amounts to a scanning of the solar image, allowed of observations of the solar limb and solar disk in a particular wavelength, usually that of Hα. The problem of observing the corona, the brightness of which is only about that of the moon at first or last quarter, posed many problems. During a total solar eclipse straightforward photographic and spectroscopic techniques could be used, but at other times the glare of the sun's disk (the photosphere) and the light scattered by it in the terrestrial atmosphere gave nil results using any customary method. The problem was solved by Lyot who developed his now famous coronagraph. The basis of the instrument is simple enough—the telescope, for telescope it is, has a non-achromatic single-element objective and beyond it is a long dust cap containing an internally greased tube to trap any dust particles. The image formed by the object-glass is brought to focus on an opaque disk and this is examined by a field lens and simple eyepiece. Careful attention to details of design, especially those factors connected with the scattering of light within the instrument, together with its use only at high altitudes (e.g. at the Pic du Midi, 2862 m), brought most successful results. The development of a highly selective monochromatic filter and the use of a grating spectrograph provided a means of obtaining coronal spectra in daylight. All these techniques have enhanced the knowledge of the solar physicist and have prepared the way for profitable investigation of the terrestrial effects of solar phenomena.

What the I.G.Y. has given the solar physicist is an organization which has enabled a world-wide coordinated scheme of observation to be carried out on the relationship between solar and terrestrial phenomena. For solar research this brought the system of world alerts already mentioned and, not least, the possibility of a 24-hour recording of solar activity. In fact now that the formal phase of the I.G.Y. has ended it is good news to find that 89·7% success has been scored in respect of this overall coverage. A standardized method of recording observations has been used and when the observational material is fully " processed " then the astronomer will have a quantity of vitally useful information to aid him in a greater understanding of the

* A lecture to the Education Group, given at the Institute's House on March 4, 1959

mechanism of solar activity. Furthermore, as the sun is a star these results will be of considerable significance to the study of the stellar mechanisms in general.

In the past the study of solar activity has not been confined to the sun itself. For a long time the relationship between solar and geophysical phenomena has been examined. What has been lacking, however, is an all out attack on the problem. For this the I.G.Y. has provided a unique opportunity—or perhaps it would be more correct to say that providing such an opportunity was the *raison d'être* of the whole concept of an International Geophysical Year. The attack may be said to have taken place on two fronts. Firstly it was necessary that observations should be made as continuously as possible and also to arrange that they should be intensified at times of exceptional solar activity. Secondly it was required that observations should be made simultaneously over as wide an area of the earth's surface as possible. This made it desirable that observing stations should be established at places never before used as such. More particularly, in view of the geomagnetic nature of so many of the terrestrial results of intense solar activity, the establishment of observing stations on the Antarctic continent was much to be desired. The use of these has been more than profitable. The southern aurora has been carefully observed and other geomagnetic phenomena have been regularly studied. For auroral observing in Antarctica and in the I.G.Y. at large, much use has been made of the all-sky camera. This beautifully simple device gives a 360° coverage of the sky by using a convex mirror mounted with its axis vertical. A small mirror lying above the convex mirror and directly in line with the latter's optical axis causes the rays from all over the sky to return through a circular aperture in the convex mirror and the image is formed on photographic film at the base of the instrument. In this way photographic records have been prepared of aurorae with the whole of the hemisphere of the sky visible at a glance. The camera also contains a clock, the image of which is recorded on the film so that time of each exposure may be recorded automatically. There is no need to stress the importance of having observations made in Antarctica as well as in high northern latitudes. Moreover with so many observers in both hemispheres it has been possible to ascertain the forms of the aurorae simultaneously at each pole. A word of praise must be given to the many British amateur aurora observers who, under the direction of Mr. James Paton of Edinburgh, have materially contributed to the success of the work.

One of the aims of those who planned the I.G.Y. was to have wide-scale geodetic measures carried out, so that a better understanding might be obtained of the figure of the earth. They themselves did not, probably, fully realize the great strides which would be made in the solution of this problem by the launching of artificial satellites, but we shall return to this later. Meanwhile reference must be made to the Markowitz moon camera developed for permitting wide use to be made of observations of the moon and the star field surrounding it. As is well-known, precise measures of the moon's position are usually made during occultations. These times are particularly appropriate, for the positions of the occulted stars can be particularly well determined. By observing both the beginning and end of occultation corrections to the moon's computed position may be made and also more accurate determinations of the terrestrial position of the observer. These in turn lead to corrections in the earth's figure. However, the organizers of the whole scheme appreciated that if observers were to wait for appropriate occultations the number of determinations which could be made would be too few. In addition, occultation observations require an equatorially driven telescope and some practical observing experience. It was, clearly, desirable that some other method be evolved. Both the requirements of frequent and regular observation and universal applicability would be met if some technique could be devised for photographing the moon and its surrounding star field whenever required. The trouble was that any exposure suitable for a star field would give an over-exposed image of the moon and, furthermore, the differential motion of the moon itself and the surrounding stars would raise complications. The Markowitz moon camera is an ingenious attempt to offer a practical solution to these problems, with the additional advantage that the need for an equatorially mounted telescope was obviated !

Firstly, the camera has the photographic plate mounted on a sliding holder which is actuated so that it moves across the camera at a rate corresponding to the apparent star drift caused by the diurnal rotation of the earth. The rate in seconds of arc per second of time depends on the declination* of the star and the driving mechanism is adjustable to allow for this. Thus the observing telescope itself requires no equatorial mounting or driving clock. Secondly, the disparity in brightness between the lunar and stellar images is taken care of by passing the moon's image through a plane-parallel dark neutral filter. This filter is circular in outline and is pivoted about two diameters. The pivoting of the filter causes a refraction displacement of the lunar image and the rate the filter's mechanical motions are so adjusted that they counteract for the movement of the moon against the background of the fixed stars. The third requirement is thus satisfied and the camera design offers a means of permitting frequent, regular and widespread observations to be made. Measurements of the plates can, of course, be carried out at selected centres. A number of cameras of this type were made and distributed to observers participating in the scheme, and the work carried out with their aid has been successful.

Another method of attacking the problem of determining latitude and thus figure of the earth is to observe the exact moment when a star of known right ascension† and declination reaches a particular altitude. Again careful observations have to be made if they are to be of sufficient accuracy to provide the information required. Yet this means using only experienced observers unless some semi-automatic approach can be devised. Such an approach should also take care of the observer's personal error in estimation of the moment when the

* The declination of a heavenly body is its angular distance due north or south from the celestial equator.

† Right ascension is measured along the celestial equator in an easterly direction commencing at the point of intersection of the celestial equator with the ecliptic.

star reaches the required altitude. Professor Danjon of Paris provided an elegant solution in the form of his "impersonal astrolabe." The basic principle of the instrument is the provision of two optical images of the star under observation, and these the observer must keep coincident. If this is done then the astrolabe itself "does the rest." It may be of interest to enquire how this is achieved. Two primary images of the star enter the astrolabe's objective. One is a direct image which reaches the objective via a prism. The second is a reflected image from a bowl of mercury which also passes through the prism to reach the objective. Both images pass to a compound Woolaston prism. The doubly refracting properties of the prism, together with the construction of the prism block, cause each of the two images from the objective to be split into two parts. The outer images are then suppressed and the inner two pass to the eyepiece. The coincidence of these two latter images will be dependent upon the altitude of the star and the position of the Woolaston block. Clearly then there will be one position, and one only, of the prism block which will cause coincidence of the emergent rays when the star is at some predetermined altitude, say 60°. The operation of the instrument is simple. The prism block is moved along the optical axis by a motor drive and observations are begun before the predetermined altitude is reached by the star. The operator controls the rate of motion of the Woolaston prism so that coincidence of the images is maintained. Observation continues until after the predetermined altitude has been reached. When the star reaches this altitude the Woolaston prism will be in a particular position, and matters are so arranged that at this point an electrical contact is closed. In this way the time at which the star reaches the set altitude is automatically recorded. As the observer has only to keep two images coincident and has no call to estimate the instant of reaching the predetermined altitude, the question of personal equation does not enter and vitiate the results. Moreover the main body of the instrument remains horizontal during use and the eyepiece is inclined at such an angle to the horizontal as makes for ease of observation and lessens fatigue.

Probably the most spectacular of all the I.G.Y. activities has been the launching of artificial satellites. Shorn of the ballyhoo and glamour which has surrounded this whole form of investigation there is here a really new and important development. For the first time scientific investigation is possible in two new "dimensions"—on the one hand the upper air can now be sampled and be used as an experimental medium, on the other hand "vehicles" of known mass and design can be placed in orbit and thus not only give information on the figure of the earth, but also on the density of the uppermost reaches of the air and evidence which may well have implications for the fundamental laws of dynamics. Observations of the satellites by both amateurs and professionals in the United Kingdom have already proved the worth of this kind of investigation. There is, of course, the "romantic" aspect of space travel. Whatever may be the profound technical difficulties which face those concerned with putting man into space, if (or should one say *when* ?) this occurs, then there is immediately to hand a very powerful tool for further investigations into the universe. Not, let it be said, primarily because it may be possible to initiate scientific interplanetary exploration, but because the establishment of instruments on, say, the moon will allow of an examination, without any filtering by the earth's atmosphere, of extra-terrestrial radiations which, after all, are our sole source of factual knowledge in astronomy and cosmology. But the importance, implications, and political significance of this research have raised many questions, and it may now be appropriate to turn briefly to the educational and wider aspects not only of this endeavour but also that of the whole I.G.Y.

Educationally it would seem that the I.G.Y. has many facets which are of importance. There is, of course, the whole matter of synoptic observation. Whatever the ingenuity of the apparatus used and the expertness and ability of individual observers, it is the widespread and synchronized nature of the observations themselves which has made the I.G.Y. so powerful and effective a weapon to use on the problems which it was planned to attack. This would appear a useful aspect of the whole scheme to emphasize. In research in the physical sciences the very nature of much present day activity necessitates either work by research teams or, at least, wide and frequent consultation. The I.G.Y. is, surely, a "classic" example of the ineptitude of the popular picture of the scientist as a lone figure working away without concern for anything or anyone but his own isolated experimental results. After all, if young people are to enter the scientific profession, then it would be as well if the kind of co-operative professional life which they are to take up is understood as soon as possible.

Another facet of the I.G.Y. program is the relationship between celestial and physical phenomena. While it is well-known that astronomy is not a "school subject," that it is not in general a subject for the examination syllabus, here would seem to be an excuse to bring in a little basic solar physics as well as something about spectroscopy. Of course the physics teacher is limited in what extra-curricular subjects he can find time to discuss but perhaps such items, even briefly referred to, may be of use as a stimulant if nothing else. Yet there is more to it than this. These facets of the I.G.Y. may assist in breaking down the artificial barriers which still exist in education in science—barriers which can, surely, do nothing but harm as they encourage young minds to departmentalize and pigeon-hole their knowledge.

Moreover both aspects here mentioned show how discovery and development has been made by co-operative observation, using previous knowledge as well as techniques both old and new. Perhaps they can also help to explode popular fallacies about scientific research as an activity. Such fallacies are still only too prevalent outside the scientific community. There is a true story of a young qualified man who was employed in a small firm to test and operate a "quality control" of products from the small factory. The men in the factory had planned to go on a one-day "token" strike on a certain Friday, and the young scientist therefore applied for the day off; it was obvious that there would be nothing for him to do. He was, however, refused permission and instructed, quite seriously, to spend the day "on

research"! Surely the planning and work of the I.G.Y. can be made to show something of what a research program is and how it operates.

Again it would appear that there is always an interest shown in how things work and how observations are made. The Markowitz moon camera, Lyot's coronagraph and the Danjon impersonal astrolabe can act as excellent examples. They were designed to tackle specific observational problems and their very methods of operation bring before any student a number of basic physical principles and techniques. What is more, a discussion of their working once again provides a link between matters celestial and terrestrial. There is also another educational aspect which they may well be able to serve—the problem of teaching the experimental approach. Too often the laboratory is used as a place for self-demonstration, too seldom do students set out on their own exciting voyages of simple discovery. The problems faced by Lyot and Markowitz were simple enough in their essentials. The questions which they sought to answer are not *per se* difficult to understand. Yet both provided ingenious and highly satisfactory solutions and, as there is always a need to be able to "design experiments," it is suggested that one problem could be used as a case-history, as an example of "how it is done," and the other as a challenge for each student to tackle in his own way, using such knowledge as he has available to him. Perhaps the Danjon astrolable could also be used as an exercise in this way, although it provides a rather more sophisticated problem than the other two. Moreover, the approach to the problems should, it is suggested, go back far enough so that the need for designing a coronagraph or a moon-camera can be appreciated by the student. The educational implications of earth satellites and rockets will be obvious, although perhaps it is permissible to emphasize that it is the basic principles which can be brought out which can make discussion of them profitable as well as the wider question of the importance of this kind of research itself and the fact that the knowledge so gained may have repercussions in many other fields of science.

To-day much is being said and written about the gulf which exists between science and the humanities. There is a very good case to be made for considering natural science as "the foremost of humane studies." Many scientists realize this and it would seem that the "humanist" is the one who has to be really convinced of the correctness of this outlook. Perhaps the task would be made easier if the scientist appeared to be more interested in both the implications and administration of research. In this respect the I.G.Y. would appear to be an excellent example. It may, therefore, be appropriate to end by considering very briefly what may be termed the "political" aspects of this immense international effort. The first is the international nature of fundamental scientific research. This has shown itself time and time again in the formation of the various international scientific unions which have been mercifully "free" of politics and concerned with the co-ordination of observational effort, in co-operation in the exchange of information and in standardization of terminology. With the I.G.Y. these organizations, under the umbrella of I.C.S.U., have entered on a profitable phase of planning to a scale of unprecedented size. When it is realized that 67 nations have taken part and that observations have been made the world over with, in addition, many nations co-operating in the continent of Antarctica, the organizational headaches which had to be overcome may well be imagined. But it has not been just a matter of solving organizational problems—there has been the question of running so vast an enterprise with observing stations situated all over the globe. In addition there have also been the problems inherent in stepping over national barriers and drawing aside iron curtains. It is perhaps here that the international nature of scientific endeavour has shown itself most clearly. Moreover it is the scientific community itself which has carried out this co-operation and kept it going during the six years of planning as well as the eighteen months of the I.G.Y. itself.

The observations made in Antarctica have been useful, so useful in fact that expeditions and observational programs are to continue. In this connexion one can only fervently hope that the scientists' first continent will be left to them. Here, for the first time in history, is a large, even if inhospitable, land devoted to scientific expeditions. Here are activities which will certainly add to our fundamental scientific knowledge and where scientific teams are working with a common international aim at heart. It is a lesson which has important application in the world to-day, for in fundamental scientific research we have an activity truly independent of national aims. With the present upsurge of so much nationalism and power politics, it is salutary that the claim which the scientist has always made for pure seeking after knowledge as his driving force, is borne out in the work and results obtained in his greatest international co-operative effort so far. There would seem also to be a corollary, namely that the scientific activity is a means towards integration of national aims. Perhaps if we but realize it, we shall see that it is the most "humanizing" of man's twentieth century activities. The success of the I.G.Y., if only understood and publicized, can provide an important signpost to the humanist and the politician. The route to which this signpost points is one of which the politician must take heed. It is no longer correct to adopt an administration in which the scientist plays second fiddle and is excluded from those conferences where matters of policy are decided. There is no reason why the scientist, who is a human being as well as a man with specialist knowledge, should not be permitted to take his proper place. Indeed at the present time it is vital to the world's well-being that he should do so. This is not, of course, a plea for the scientist to act as conductor of the orchestra of state, desirable though this might be from time to time, but to draw attention to the fact that it is now necessary for him to take his seat on the front desk of the first violins. While this should be happening now, it must be realized that before it does occur there must be education at all levels if our hopes are not to remain day-dreams. The I.G.Y. can be used as a present, practicable and, if properly approached, powerful, way of showing science at work and the scientist as a leading organizer and humanist in the world of the mid-twentieth century.

Physics in the Australian Defence Scientific Service*

THE Australian Defence Scientific Service of the Department of Supply includes research laboratories working on the scientific and technical problems which arise from the defence requirements of Australia and the British Commonwealth. The Chief Scientist is head of this organization.

There are three major laboratories in the Australian Defence Scientific Service, namely: The Weapons Research Establishment at Salisbury and Woomera, South Australia, the Aeronautical Research Laboratories at Fishermen's Bend, Victoria, and Defence Standards Laboratories at Maribyrnong, Victoria, with branch laboratories at Alexandria, New South Wales and Finsbury, South Australia.

The fields of science covered by the Service are naturally diverse but physics is one of major importance and some 140 of the 550 scientists are classed as physicists.

The following is an account of some of the work involving physicists which will serve to illustrate the wide variety of work in progress. It will be seen that this ranges from basic research to the development of specialized equipment, including that for precision measurement. The examples do not fall into a few simple classes, so no attempt has been made to arrange them in any particular order—they are simply listed under the heading of the name of the laboratory where the work is being done.

Aeronautical Research Laboratories:

MATERIALS DIVISION

The Materials Division of A.R.L. is doing research into solid state physics, principally that part concerned with the plastic deformation and strength of metals. In order to carry out this work research is also being done on the essential techniques such as electron diffraction and microscopy and X-ray diffraction. For clarity the work is reported under the normal sub-divisions used in this field:

Dislocation Theory.—A new theory has been proposed to extend Cottrell's theory of the sharp yield point and to explain several experimental observations, in particular micro strain before yielding and the delayed yield phenomenon, which are inexplicable on the old theory. The new model allows dislocations to move with their atmospheres under stress before dislocation breakaway occurs. Experimental verification of predictions of the theory has been made while the yield stress/temperature relationship derived from it is in good agreement with observations on several body-centred-cubic metals in which Cottrell locking occurs.

The theoretical work has been extended to study the relationship between Cottrell locking and the type of temperature-sensitive brittle behaviour found in iron. Application of the yield-stress/temperature relationship derived in the above analysis has led to a theory which explains the effect of grain size and rate of loading on ductile/brittle transitions. Similar ideas formed the theoretical backing to the production of chromium which was ductile at room temperature.

Plastic Deformation.—One of the major drawbacks to the development of an understanding of work hardening in metals is the assumption that the processes occurring in the bulk metal are represented by surface observations. Two complementary methods for revealing "interior" behaviour have been developed. In the first process, dislocations are delineated by precipitation of a controlled impurity content after the deformation has been studied in the normal way. The technique has been found much more sensitive than surface observations, and it is already clear that the slip processes detectable on the surface are considerably more complicated than in the interior. A further important factor determining plastic behaviour—the relative lengths of the various possible slip systems—has been discovered as a result of this work. The second means of investigation is a type of X-ray microscope in which an image of the lattice misorientations in a shallow layer near the surface is produced. The surface may be removed by electropolishing and the interior studied.

The geometry of plastic deformation has been studied in single crystals of various compounds isomorphous with CsCl. The glide direction was found to be dependent on the interatomic bonding energy. Ionic crystals slipped in $<100>$ directions whilst metallic crystals slipped in $<111>$. This behaviour can be explained in terms of the energy of the stacking faults formed during $<111>$ glide. The work has been extended to compounds having the NaCl structure.

Fatigue of Metals.—It has been established that fatigue deformation of copper under low stress ($\pm 10{,}000$ lb./in.^{2}) is different from that at high stress ($\pm 25{,}000$ lb./in.^{2}), and that high-stress fatigue and tensile deformation have many features in common. Thus slip in low-stress specimens occurs in "packets" of approximately 1000 Å interlamellar spacing while slip in high-stress and tensile specimens is in the form of individual slip bands. Fatigue cracks are characteristically associated with the slip packets in low-stress samples, but tend to be intergranular in high-stress cases. Again, fractured high-stress specimens and deformed tensile specimens recrystallize on annealing and the hardness decreases suddenly, whereas no recrystallization occurs in low-stress samples and the hardness drops in a two-stage fashion over a wide temperature range. There is also a fairly gradual release of stored energy on annealing low-stress specimens compared with a sharp release over a much narrower temperature range in a tension specimen.

On the other hand, the hardness of copper fatigue specimens at fracture is the same within comparatively

* Communicated by W. A. S. Butement, C.B.E., F.Inst.P., Chief Scientist, Department of Supply, Melbourne

narrow limits irrespective of the stress level at which they are tested. This applies even for initially cold-worked material where the original hardness is considerably greater than the final fracture hardness so that in this instance, hardness actually decreased during fatigue.

It cannot be claimed that all these phenomena are at present understood. However, a theory of the fatigue process which has been developed suggests that the tendency for slip packets to be produced should increase with the number of stress reversals. Hence the distinction between the low and high-stress cases probably results from the much greater number of stress cycles required to produce fracture in the former instance.

A theory of the propagation of a fatigue crack has been developed. Repeated stress reversal will cause progressive work hardening at the tip of a crack which will lead to crack growth provided the peak stress is sufficiently high relative to the fracture stress. For the growth of a simple crack the predicted dependence of crack length on stress, number of cycles, etc., appears to be in good agreement with experiment.

Creep of Metals.—A study is being made of the mechanism of creep deformation in pure aluminium and some of its simple alloys along two main lines ; firstly a study of the structural changes occurring during the slow strain at room temperature of single crystals of aluminium, and secondly, an investigation of the effect of creep stress at elevated temperatures on the recrystallization behaviour of polycrystalline aluminium that had been cold-worked prior to the creep deformation.

In the first project, strain rates have been varied over the range 0·4% hr – 0·0015%/hr and the crystals have been examined by optical X-ray and electron microscope techniques after approximately 1% strain. It has been found that as the strain-rate was reduced, there was an increasing tendency for clustering of the slip lines, but even at the slowest rate of strain, " slipless flow " of the type described by Hanson and Wheeler was not operative. This type of study is being extended to alloy systems.

With the prestrained polycrystalline aluminium, it has been found that for both lightly and heavily prestrained material, increases in creep stress accelerated progressively recovery and sub-structure growth, but retarded the onset and subsequent rate of progress of recrystallization. These observations have enabled some suggestions to be made as to the relative importance at various stress levels of the recrystallization and stress-recovery processes which are operative during the creep deformation.

Electron Microscopy.—The observation of the surface effects associated with slip processes in metals, particularly " fine " slip, is of considerable interest. In addition to the development and application of high resolution, high contrast replica techniques, attention is being devoted to means for the quantitative determination of step heights resulting from glide in both single and polycrystalline material. One method which is being investigated involves the application of electron stereomicroscopy to this problem. Recent theoretical and experimental work, however, has indicated that this technique may introduce serious errors in the determination of vertical elevations of ~ 100 Å and means are being sought for overcoming these limitations.

Other electron microscope techniques which are being investigated include a method for selecting a given small area of a specimen for examination, " extraction " replica techniques and the direct examination of thin metal foils without the use of an intermediate replica.

X-ray Diffraction.—A method which is proving to be of considerable use in the examination of structural defects of single crystals or coarse grained polycrystalline samples is a divergent beam Laue technique employing X-radiation from a microfocus X-ray tube. The method is based upon a technique described originally some years ago by Schulz and has been further developed in A.R.L. (R. A. Coyle, A. M. Marshall, J. H. Auld and N. A. McKinnon, *Brit. J. Appl. Phy.* 8, p. 79, 1957.) The high resolution and high sensitivity to lattice distortion is derived from the use of a small X-ray source. Consideration is now being given to means for reducing the focal spot size below its present value of about 50 microns.

In addition to the recording of diffraction spectra on film, counter techniques are also in use. These are employed in particular for applications where X-ray line profile and intensity measurements are of interest.

Electron Diffraction.—Recently electron diffraction equipment has been added to the facilities of the Materials Division. A high resolution electron diffraction camera has been constructed in A.R.L. and is at present being used for the study of oxidation and corrosion processes in metals and for the examination of defects in thin metal films.

Apparatus is now under construction for extending electron diffraction studies to the scattering of low energy (10 – 300 eV) electrons from adsorbed films on metal surfaces.

AERODYNAMICS DIVISION

Techniques used in Transonic Aerodynamics.—In the transonic wind tunnel, Schlieren and direct shadow techniques are used for flow visualization and enable the position and movement of shock waves and flow separation and other phenomena to be observed without disturbing the air flow. For these techniques, high intensity light sources requiring exposure times as brief as one microsecond are frequently used. A drum camera is used for measuring the actual flash duration, and checking for faults such as multiple exposure.

In the same tunnel, Mach number is determined using two Boulton-Paul automatic absolute manometers. These are capsule type manometers, which are automatically self balancing and give remote indication at various stations to an accuracy of $\pm 0{\cdot}01$ in. mercury. For measuring the accurate models frequently required, an optical coincidence gauge has been developed. For a 100° range of surface slopes, and for radii of curvature down to 0·03 in. the error for a single setting does not exceed 0·00015 in.

Strain gauge force measuring equipment consists of a mechanical system designed to differentiate between the various force components required (e.g. lift, pitching moment and drag). Bending stresses produced by these components in the flexure strips are transformed into changes in electrical resistance of suitably mounted strain gauges. A self-balancing strain gauge bridge is

normally used to convert these changes to movements of indicating drums. This equipment is extremely stable and its sensitivity such that strain variations of the order 10^{-8} may be detected.

Free and Forced Convection of Heat from Fine Wires.—Heat transfer from fine cylindrical wires has been studied for the range of low Grashof numbers and low Reynolds numbers which are important in instrument applications.

In the case of free convection the rate of heat transfer has been shown to be a function of Grashof number (Gr) alone, even for Grashof numbers as small as 10^{-9}, provided that the aspect ratio (l/d) is sufficiently great. A theoretical analysis yielded a solution for the two-dimensional rate of heat transfer and showed that the process is two-dimensional if $Gr^{\frac{1}{3}}l/d$ is large. Interference photographs of the heated air film which surrounds the wire were used to establish a physical picture of heat transfer by weak natural convection.

Forced convection measurements have shown how the dependence of heat transfer on Reynolds number is modified by the influence of buoyancy temperature loading and the aspect ratio of the wire. Comparison of the results with the classical law of King reveals significant deviations at low Reynolds numbers. A more accurate law has been constructed for this region. A further comparison with a relation derived by means of the Oseen approximation shows that this relation is approached asymptotically as the Reynolds number tends to zero.

Wide-Range Hot-Wire Anemometer.—This equipment measures steady velocities from 0·1 ft/s up to supersonic speeds and also fluctuating velocities as small as 0·01 % of the mean stream velocity in the frequency range 2 c/s up to 80 kc/s. The sensing element is an electrically heated fine wire of 0·0001 in. dia. platinum for speeds up to 100 ft/s whilst a tungsten wire of 0·0003 in. dia. is used at higher speeds. Wire temperatures up to 300°C are employed. The steady velocity component is measured on a non-inductive Wheatstone bridge, the fluctuating component being fed into the amplifier and finally detected on a thermal milliammeter. The falling response of the wire with increasing frequency due to its thermal inertia is corrected by a variable time constant circuit in the amplifier. A differentiating stage permits the measurement of velocity derivatives, a facility which is important in the fundamental study of turbulence. A set of sharp-cut-off low-pass filters allows the frequency range to be varied from 2·5 kc/s to 80 kc/s. This enables the best signal/noise ratio to be achieved consistent with the frequency range to be measured.

Defence Standards Laboratories :

Radio and Microwave Applications.—One section at D.S.L. is engaged in applying radio and microwave techniques in the study of physical problems. Nuclear and para-magnetic resonance methods are being studied together with gas absorption microwave spectroscopy. A microwave interferometer for observation of the propagation of detonation in confined explosives is providing experimental information about the initiation and growth stages of detonation.

The microwave facilities cover the X, K and Q bands and these frequency ranges are gradually being extended to give a complete coverage from about 5 to 40 kMc/s. A multiplier system to provide a microwave frequency standard based on the laboratory 100 kc/s standard is in operation.

X-Ray Crystallography.—A section at D.S.L. is using X-ray diffraction for crystallographic structural investigations and for more routine qualitative and quantitative analytical and metallurgical studies. The equipment includes a Philips diffractometer, a Unicam Weissenberg goniometer and a number of powder cameras. The structural investigations are at present concerned with the elucidation of the structure of certain organic titanium esters.

These esters form a series related to butyl titanate used for a most successful heat and weather resistant paint developed at D.S.L.

The routine problems usually have their source in other groups of the same laboratory and have a wide range. Problems recently studied include plastic deformation in the brittle fracture of chromium, " poisoning " of pure lead anodes in electrodeposition, the examination of corrosion products and the quantitative determination of anatase in titanium dioxide pigments.

Optics.—The Defence Standards Laboratories activities in optics consist mainly of design and construction of optical components, critical examination of optical instruments, and relevant research. Most of the work arises from defence requirements, but other research institutions (Government or University) are also assisted; direct contact with private industry is limited to an advisory service.

The design projects include the investigation of Service optical instruments, with the aim of reducing the total number of different types of glass required ; and, for Mount Stromlo Observatory, the design of a spectrograph camera which will facilitate the estimation of radial velocities of stars. Desk machines are being used for the calculations at present, but it is hoped that it will soon be possible to use Australian digital computers for the purpose.

There is a steady demand for the constructional, testing and advisory services of the workshop and laboratory. In view of the increasing interest being shown in multi-layer dielectric filters, a recording spectrophotometer has proved particularly useful.

Current research includes an experimental study of certain asymmetric interference fringes, and the examination of methods of allotting manufacturing tolerances by the use of modern criteria for image assessment.

Metrology.—Research, in the field of metrology, while aimed primarily at the improvement of facilities for the verification of standard equipment for measurements of length, mass, time, volume, density and atmospheric pressure, is also applied to the problems of precise measurement and control in production and inspection.

Attention has been given to the problem of measuring temperatures during comparisons of standard gauges leading to the development of a thermocouple apparatus with a breaker-type amplifier to read temperatures in

the neighbourhood of 20°C. to 0·02°C. and capable of measuring small temperature differences to 0·002°C. This apparatus is revealing greater temperature gradients than suspected both within static measuring apparatus and arising from friction between moving parts, such as between a lead screw and its nut in a high precision dividing machine. It has also been applied to determinations of the temperature effect in studies of the direct impingement air jet of the type used in air gauging apparatus. The work on pneumatic gauging systems has also covered the forces due to the air jet and the sealing properties of closely-fitting surfaces against air leakage.

Temperature Measurement.—To cope with constant demands for better accuracy in temperature measurement, temperature standards calibrated directly in terms of the International Temperature Scale are maintained, and investigations aimed at increasing the accuracy with which measurements can be made are carried out. The standards so calibrated are subsequently used to calibrate secondary reference or working standards for use in science and industry, including precision liquid in glass thermometers (– 80° to + 550°C), platinum thermocouples (0° to 1550°C), and disappearing filament optical pyrometers (800° to 2500°C).

The performance of the Smith resistance thermometry bridge used in connection with this work has been investigated, and it has been shown that errors in temperature measurement due to irregular resistance drifts in this bridge can be reduced to ± 0·0005°C in the range 0°C to 100°C and ± 0·001°C at 630°C, by the simple process of checking the bridge against various sections of an external decade of 10 ohm resistors. A very stable decade employing a new method of construction has been developed for this purpose, and two papers on this work are in the course of publication.

Recently, attention has been given to the reproducibility of the triple-point temperature of water (in terms of which the zero point of the International Temperature Scale is now defined) and, in particular, to effects due to variations in the isotopic composition of water. It has been concluded that with only moderate precautions these are not likely to exceed ± 0·0001°C, and confirmatory measurements on samples of Melbourne water at various times of the year, and on samples obtained from Antarctica and the Victorian Alps, have agreed to within this figure.

A considerable amount of calibration, advisory and investigational work relating to equipment for the measurement and control of temperatures in industrial processes is done directly for various factories engaged on defence work. In this connection, it may be mentioned that an investigation is in progress to determine the thermoelectric stabilities and life expectancies of several of the different makes of chromel v. alumel type thermocouple wires which have come on to the market in recent years.

Radiological Physics.—Work in this field is closely associated with physical and instrumental aspects of industrial radiography, using both X-rays and radioactive sources. It is also concerned with the development of instrumental inspection techniques to replace normal radiography on film, and, consequently, is concerned with problems associated with the measurement of radiation intensity. It is also involved, to a lesser extent, in theoretical investigations into the scattering and absorption of X and gamma rays.

For making measurements of the peak kilovoltages applied across X-ray tubes, a new voltage divider technique has been developed. Peak kilovoltages up to 150, both positive and negative, can be measured with an accuracy of better than ± 1% on any conventional type of X-ray equipment. The technique makes use of relatively simple components and is easy to set up and use.

The D.S.L. equipment for checking the internal assembly of certain types of artillery rocket motors is a simple but elegant development in the instrumental inspection field. It uses a small gamma ray source (radium or cobalt 60) and three Geiger tubes, together with associated electronic and recording equipment, and is largely automatic in operation.

Arising out of theoretical work on the determination of the energy and angular distributions of the radiation intensity at various distances from a given X or gamma ray source, a new formula has been derived for the total gamma ray absorption coefficients of air in the energy range 0·1 to 10 Mev. This new formula, which yields results in agreement (to within 1%) with those calculated from the three complex theoretical formulae for the various contributory absorption processes involved (viz. Compton scattering, the photo-electric effect and pair production) is a relatively simple one. It should be generally useful, especially in major investigations involving the use of a digital computer, since it enables the calculation of absorption co-efficients to be readily programmed.

Electro-Photography.—Research and development in electro-photography was initiated by the South Australian Branch of D.S.L., with a view to exploring its scope and limitations, especially for radiography. This work is likely to further our understanding of the photo-conductive mechanism in a number of electrical insulators when they are irradiated, and of the behaviour of metallic and other particles in insulative dispersion media.

Electrophotography, or Xerography as it is more widely known, is an electrostatic image forming and recording system which is adaptable to photography, radiography, printing and pattern formation ; it is characterized by high resolving power, by very rapid developing techniques and by images capable of manipulation after development. In Xerography, electrically charged photo-conductive materials replace the silver halides as the recording medium, the latent electrostatic images formed thereon are rendered visible by development either with dry powders (the American system) or with particulate suspensions, colloids or solutions (the D.S.L. system).

The liquid development system, introduced by D.S.L., has shown Xerography to have a much wider scope than was originally anticipated ; potential applications for Xerography now include continuous tone photography, colour printing, micro-radiography, electrocoating, electro-separation, magnetic development, cartography, textiles and data recording.

Interstitial Graticules.—Graticules, which are precision scales on glass, are essential components of many instruments used by the Defence Services. In the past the types available have all had the pattern on the surface of the glass disc. Unless covered by a cover-glass, which is generally undesirable for a number of reasons, these patterns are exposed to damage by such agencies as fungi, moisture, high humidity or abrasion during cleaning operations.

To overcome these disadvantages, D.S.L. have developed a new type to which the term " interstitial " has been applied because the graticule pattern is formed in interstices in the sub-surface structure of the glass. Two simple methods of achieving this result have been developed.

The process depends on the fact that on a molecular scale, glass has a network structure consisting of cells of irregular shape and size, some of which contain sodium ions. Selected sub-surface sodium ions can be removed and simultaneously ions from a film of silver or copper on the surface of the glass can be made to diffuse into the vacant sites in the cells. The silver and copper ions can then be reduced to atoms which are aggregated to form a visible pattern. The pattern is thus located within the glass and can be damaged only by treatments that damage the glass itself. Opaque or transparent patterns in a variety of colours may be obtained.

Spectrographic Source Unit.—A group of D.S.L. research workers interested in the study of electrical discharges used for spectrochemical analysis together with engineering staff have designed and built a source unit of greater versatility and sophistication than any other known in this field.

It provides :

(*a*) Conventional d.c. arc discharges up to 15A from a 250 volt supply ;

(*b*) Conventional spark discharges from a 15 kV, 20 mA, 50 cycle supply, charging a 0·005 μF condenser through a variable inductance up to 500 μH ;

(*c*) Pulsed-arc discharges of durations 50-1500 microsec., repetition frequencies from less than 1 per second up to 100 per second, peak currents of 2-200A and pulse shapes exponential, square, or round topped.

An electronic scaling system provides timing pulses to control :

(1) Triggering of the pulsed-arc discharges ;

(2) Extinction at a variable time after ignition of the pulse ;

(3) Opening of the spectrograph shutter after preburn time ;

(4) Conclusion of the exposure after a preset time (up to 10 minutes).

Experience indicated that for some analyses the peak current needs to be controlled to about 1% precision, i.e. rather better than could be done using an ordinary peak-voltmeter system. The problem was solved by using a C.R.O. with magnetic deflection and a magnetic neutralizing coil to offset the zero line by several screen diameters.

The unit is being used not only as a flexible analytical tool but also to provide data which it is hoped will help to elucidate some of the obscurities remaining in our knowledge of open gaseous discharge processes.

Weapons Research Establishment :

WEAPONS RESEARCH AND DEVELOPMENT WING

Non-Magnetic Mass Spectrometer.—A non-magnetic mass spectrometer has been developed. Instead of beam deflection in magnetic and electric fields which forms the basis of mass discrimination in conventional mass spectrometers, this instrument uses the principle of velocity selection of the ions as they traverse a radio frequency field. The method permits the use of ion beams of very large cross-section resulting in a large total ion current and consequently in a high sensitivity of the instrument. The simple and rugged construction of the device makes feasible its use for gas analytical work even under rough conditions. Development of this instrument to a form suitable for application to certain problems of the Services is being undertaken.

Physics Projects.—The Physics Projects Group has been working mainly in two fields, (*a*) the generation and amplification of power at microwave frequencies, and (*b*) studies in some aspects of solid state physics.

With regard to (*a*), our objective is to develop techniques and facilities which will enable us to commence studies in the generation of millimetre wave energy. As a means to this end we have worked on the design and construction of an X-band double-cavity klystron, required to have an output of the order of one watt but more particularly very free from microphony. This requirement has led to a novel type of structure being adopted in which the pressure welding of copper to copper has been widely exploited.

Our work in (*b*) has been both background research and the development of laboratory models of devices based largely on the results of the research. Photoconductivity has been studied and our work on such materials as pure cadmium sulphide and amorphous selenium has led to our suggesting modifications to details in the accepted theory and also to techniques for realizing specific practical requirements. One such application was the development of a storage device somewhat similar in mechanism to the vidicon but not incorporating an electron beam nor requiring evacuation.

In infra red our attention has been mainly confined to the 10 μ region. This is of particular interest as it is beyond the region for which even cooled photoconducting detectors have been successfully developed. Some time ago thermal detectors which combined sensitivity with unusually short time constant were developed and these have been used in conjunction with a scanning device to form the basis of an image converter for providing a thermal picture of objects only a few degrees above ambient temperature. A study of other possible phenomena on which an image converter not employing scanning might be based has been made and we are working on two which show promise of some success.

Physics of the Upper Atmosphere (I.G.Y. Experiments).—A number of problems concerning the physics of the upper atmosphere are being attacked at Woomera during I.G.Y., using the " Skylark " rocket (made available to the Gassiot Committee by R.A.E. Farnborough). The University of Adelaide also intend to participate in the program. The main part played by the Australian

Defence Scientific Service in this work lies in the provision of the facilities of the Woomera Rocket Range which include the launching of the rockets and the operation of the ground equipment, i.e. cameras, tracking of the vehicle, reception of telemetered results of experiments and so forth.

The following are some details of the experiments to be performed mainly by a group of United Kingdom Universities whose work is co-ordinated by the Gassiot Committee of the Royal Society :—

The problem of upper atmosphere winds is to be studied by a number of techniques which are sufficiently different to inspire considerable confidence in the results provided they are consistent. One method is the grenade experiment in which explosive charges are set off at various heights and the arrival of the sound waves at several widely distributed points on the ground is timed. Knowing the position of the grenade bursts from observations with ballistic cameras it is possible if certain assumptions are made to calculate not only the velocity of sound but the wind speed and direction in the layers between grenade bursts. From the speed of sound, the temperature of the air can be found. The same problems of winds and temperature are also being attacked by two quite different techniques.

One proposal is to emit a cloud of sodium vapour at altitude, which will fluoresce in sunlight (while the earth is in darkness). The movements of the luminous cloud will, of course, give information on wind, while the temperature is to be derived from a study of the doppler broadening of the yellow sodium lines. It is hoped that the ejection of sodium and other materials will throw some light on the composition and behaviour of the upper atmosphere. Wind measurement is being tackled as well by using conventional " window " which will be tracked by radar. The behaviour of this material in regions where atmospheric density and therefore air resistance are low introduces new problems.

The ionosphere has been studied intensively in the past by radio propagation methods, but in the last decade or so it has been possible to launch rockets into the ionized layers of the atmosphere and investigate conditions directly. Various types of mass spectrometers and electron density measuring equipment are to be flown during the I.G.Y. and their indications will naturally be correlated with information from propagation experiments and with other geophysical data. Apparatus is being developed for rocket borne propagation experiments which, because the transmitter actually penetrates the ionized layer, will give information not obtainable from ground based equipment.

Other phenomena which are to be examined are the day and night air glow and the incidence of micrometeorites. It is proposed by means of a proton precession magnetometer to investigate the variation of the earth's field with height, particular interest being taken in the magnitude and position of current flow in the ionosphere. The proton precession magnetometer is particularly suited to rocket experiment since it is insensitive to attitude, is readily adapted to the somewhat strenuous conditions of rocket flight, and has no calibration which can change in flight. At present, no experiments on solar radiation are envisaged, but it is quite possible that, later, this most important factor will also be studied, since it is one of the main factors determining the condition of the atmosphere.

Wind Tunnel S.1.—The Aerodynamics Division of W.R.E. is operating a 4,000 h.p. continuous-flow, closed circuit supersonic wind tunnel with a 15in. × 15in. working section and a Mach number range of 1·4 to 2·8. The instrumentation of such a facility must cover a wide range to give all the desired information.

Optical methods, such as schlieren and shadowgraph, are used to make the flow pattern around the model in the working section visible and are especially useful in shock wave and shock wave-boundary layer studies.

Pressures at static holes or in pitot tubes are recorded by either photographing a multi-tube manometer or, when a rapid response is required, by using pressure transducers and associated equipment.

The model under test is mounted in the working section by a sting which is fitted to an incidence change gear thus permitting the attitude of the model with respect to the air stream to be varied during a run. Strain gauge bridges are attached to the sting and are so located that the outputs give a measure of the aerodynamic forces and moments acting on the model. These outputs are continuously monitored on chart recorders as the test proceeds and are scanned at discrete intervals and the values recorded on tape for subsequent analysis in a digital computer.

TRIALS AND INSTRUMENTATION WING

Ultra Wide Angle Lens.—The problem of measuring the vector miss-distance and relative attitude of an anti-aircraft missile relative to a target aircraft can conveniently be solved by photographic triangulation methods if two groups of cameras each with a spherical field of view can be installed on the target aircraft with a reasonable base line between them (for instance one at each wing tip).

It is important that each group of cameras is—

(1) Small, to allow a low drag installation ;
(2) Light, to help avoid flutter troubles on wing tip application ;
(3) Of low cost, as the system is expendable.

An attractive solution was two cameras to each group, each camera being equipped with a lens with a field of view of over 180°. As no suitable lenses were available the development of such a lens was undertaken and a two component system covering a field of 210° solid angle was produced. This lens has an equivalent aperture of f9 and is capable of resolving 350 lines per radian in the centre of the field dropping to 115 lines per radian at the edge of the field, the resolution being measured with a high contrast chart and Ilford HP3 film.

The lens design is unorthodox in that it is arranged so that equal angular increments in the object space are re-produced as equal linear displacements in the image plane. This arrangement of course produces radial distortion, but it is ideal for angular measurement—the purpose for which it is required.

Data Processing.—The Weapons Research Establishment has recently put into operation a comprehensive system for the processing of range trials data. The system automatically produces calibrated or analyzed

results of trials in either tabular or graphical form and has greatly increased the capacity of the Establishment to deliver results promptly without increasing staff.

Essentially the system carries out four operations on the raw data received from guided missiles :

(1) The recording on magnetic tape (chosen for its versatility, cheapness and re-usability) of instrument readings conveyed to ground by radio telemetry, together with elapsed time.

(2) The automatic measurement of these data and the recording of the measurements on a second magnetic tape in binary digital code in a form suitable for direct replay into our electronic digital computer. (WREDAC).

(3) The automatic calibration and analysis of the measurements by the computer working to an appropriate set of instructions. The results are recorded on a third magnetic tape.

(4) The automatic display of these results in either graphical or tabular form by the use of high-speed printers and plotters under the control of the third magnetic tape.

It is interesting to compare the advanced semi-automatic system which was replaced by the fully automatic system in terms of speed of operation. To process 10,000 telemetered points using the semi-automatic system occupied 20 working hours. Using the fully automatic system the work is completed in 15 minutes. Generally the results produced by an automatic system are of higher accuracy and of greater reliability than those produced manually.

The W.R.E. system was the first complete electronic system for the processing of guided weapons trials data in the free world. There is no doubt similar systems can greatly increase the scope and accelerate progress of all the experimental sciences.

The Determination of the Performance of Weapons.—Considerable effort has been devoted to finding the most efficient way of judging weapon performance. One method is to fire weapons under a number of conditions within the required operational region according to a statistical plan. By analysing the recorded miss distances it should be possible to determine the effectiveness throughout this region. However, as there may be many random factors affecting performance this approach demands the firing of large numbers of expensive missiles.

Alternatively, since we know the physical laws the missiles must obey, if we can find out its properties and those of its inputs we may deduce its behaviour. Much of this can be done in laboratories. Some rounds must be fired to check the magnitude of missile parameters in flight and some to confirm that the behaviour in flight does agree with the predicted behaviour, which is normally worked out on an automatic computer.

This systematic approach yields information for future missile designs and requires fewer weapons. In essence the guided missile and its associated kinematic loop is a servomechanism and so we have been able to apply mechanism techniques. Some interesting problems arise, especially those concerning unwanted high gain feedback loops which often include non-linear elements. The presence of such spurious loops may distinctly increase miss distance.

Reviews of Books

THE WAY THINGS ARE

By P. W. Bridgman

London : Oxford University Press. Pp. x + 333. Price 45s.

Many people will associate Professor Bridgman's name with his distinguished work on the physics of high pressures; fewer with the theory of operationism which he has made particularly his own. But everybody will welcome this substantial book in which he discusses at length a pain in the mind which has borne down upon him for a number of years, namely the way we use (or misuse) our intellectual tools, and why in fact we make such heavy weather in all kinds of social and individual activities, especially those directly concerned with thought.

To put the point first, the author finds a real tension between society and the person, in the sense that what is assumed to be best for the former is necessarily so for the latter. In this he claims to have been something of a rebel, reluctant (to put it mildly) to accept outright what authority decided was " good " for him. It is not surprising therefore to find him expressing subjective views for science, especially in the realm of proof. He admits that the traditional objectivity has done little harm in the physical and mathematical sciences, but sees the yellow (or even perhaps red) light in its unquestioned application through the biologists' field to the social disciplines and philosophy. In this he joins hands to some extent with somebody very different, Professor Polanyi, in his recent book entitled *Personal Knowledge*.

Professor Bridgman's general outlook strikes the reviewer as commendable, not only as an attempt to halt the prevailing gregariousness of thought, but also—and this is possibly of equal value—as a recognition that research of the highest order always contains an aesthetic element, indiscernible, as a rule, by the herd. Scientists and artists have a good deal in common.

So much for what the author says; now for the ground upon which, in the last resort, his thesis rests. This is nothing less than Gödel's theorem, or rather that portion of his general proposition which states the impossibility (given certain conditions) of constructing a proof of consistency within any logical system by the use of principles within that same system. The classic example of this, as is well known, was the failure of the great Hilbert to erect such a proof for mathematics itself, using mathematical techniques. Professor Bridgman sees only too clearly that the " moral " of Gödel's theorem applies to the whole of mankind. We have, in effect, languages and meta-languages without end, forming an

infinite regress. The malaise with which we started appears to be due to the refusal of our intellectual equipment to face this situation.

Connected closely with this state of affairs in essence, though not so strictly in demonstration, is the humiliating thought that the most that we can hope to "know" (i.e. the limit of knowledge to which we can attain) is probability rather than certainty. It is assuredly a far cry from the Victorian beliefs, with their arrays of models, rods, and levers.

This is not exactly an easy book to read, in spite of its enviable clarity of expression. The fact is that the century of the common man is demanding too much of its intellectuals. It is asking them to say "yes" or "no" to a number of basic questions, without realizing that Gödel's theorem must be mastered and accepted first, and that when that is done, and only then, can the way of sorrows towards the limited vista of high probability, rather than that of absolute certainty, be said to begin.

F. I. G. Rawlins.

THE SCIENCE OF PHOTOGRAPHY

By H. Baines

London: Fountain Press. Pp. 320. Price 38s. 6d.

It is to be hoped that the announcement on the dust cover that this book is "written for the layman" will not cause scientists to dismiss it as unworthy of their attention. True, it is made intelligible to the keen layman and the ordinary photographer by the inclusion of simple lessons in elementary science, but these are clearly marked and can be passed over by those with a basic scientific training. The major parts of the book constitute an excellent introductory account of photographic science for scientists not specialist in the field, yet who need to use photography in their work.

The book is an authoritative and comprehensive account of photographic theory and practice. After a brief historical introduction, the basic optics and chemistry are explained, leading to a description of the manufacturing processes. A survey of latent image theory is followed by chapters on the processing and sensitometry of photographic materials and a discussion of tone reproduction. Special photographic effects such as reciprocity failure and latensification are adequately dealt with, and the implications of the granular structure of the photographic image studied. The treatment of colour photography is necessarily brief in such a general review, but (as may be said of all the book) gains in comprehension by the competent brevity of the description. Finally the many scientific applications of photography are reviewed.

The attraction of this book lies in its concise coverage of the whole field of photography. The omission of references will not deter scientific readers who need to delve deeper into the subject. The style is clear and free with a refreshing absence of technical jargon.

R. G. Horner.

RADIATION BIOLOGY AND CANCER

Texas: The University of Texas Press. Pp. 493. Price $8·50.

As the subtitle states, this is a collection of papers presented at the Twelfth Annual Symposium on Fundamental Cancer Research, held at the M. D. Anderson Hospital and Tumour Institute, Houston, Texas in 1958. It is not, therefore, a book for the general reader, but for the specialist, or rather for specialists in a number of fields. The theme of the symposium, which is also the title of the book, was chosen to limit the field of discussion. Nevertheless it is still very wide, the main topics ranging from Fundamental Radiobiology, through the Radiation Effects on the Hematopioetic System and the Induction of Neoplasms by Ultraviolet light, to the Medical Applications of Radiation. Similarly the subjects of individual papers range from the frankly speculative "Radiation Neoplasia and Endocrine Systems" to down-to-earth comparison of radium, cobalt-60 and caesium-137 as gamma ray sources for interstitial radiotherapy.

The book is well produced and the presentation is pleasant. It is perhaps unfortunate, however, that the papers have been published in this way. Little would have been lost and a much wider audience would have been gained if they had been published in the appropriate journals.

W. J. Meredith.

ASTRONOMY

By Robert Baker

London: D. Van Nostrand Co. Ltd. Pp. viii + 547. Price 52s. 6d.

In welcoming the seventh edition of this best-known of transatlantic textbooks of astronomy, it will be appropriate for physicists in this country to consider its status among rivals and what place there is to-day for attempts to cover a vast topic like astronomy in one volume. It is probable that we shall never see anything better than our own Sir Harold Spencer-Jones' *General Astronomy* with its unique judgements as to how much detail to include under any heading. But Baker will undoubtedly come handier to most physicists requiring rapid access to any set of data. Baker marshals his chapters and sections so shrewdly, and American publishing methods give him so apt illustration in the many pictures so wisely selected to reinforce his brief and rapid explanations. The new edition with its shift of emphasis into radio astronomy and galactic and extragalactic investigation gives the book reinforced importance to-day.

It is, of course, arguable that the physicist now finds his data in astronomical fact to such an extent that he can no longer ignore the many separate monographs available, and that single volume compendia such as Baker are no longer required and could not possibly be adequate. But when the nuclear physicist has been mystified by volumes concerning internal structure of a star, or the optical designer has been troubled by the geometrical problems of the Schmidt camera, or the cosmologist has lost his way in trying to assess the validity of galactic research, there will be comfort in returning to this edition of Baker and regaining a sense of proportion as to observation and inference even at an elementary level. Indeed the physicist, finding Baker offering an explanation of some physical point for his general public, may occasionally have to confess that the astronomer has explained it more clearly than the elementary textbook of physics.

Martin Johnson.

RADIOACTIVITY MEASURING INSTRUMENTS

By M. C. Noakes

London : Messrs. William Heineman Ltd. Pp. viii+76. Price 10s. 6d.

This book has been written primarily as a guide for science masters in schools who wish to construct cheap and simple radio-activity measuring apparatus for demonstration purposes.

The only radiation detector dealt with is the Geiger counter ; the operation and use of this instrument is first briefly described and the remainder of the book is taken up with descriptions of associated electronic equipment such as power supplies and ratemeters, simple enough to be constructed in a school workshop. The author has assumed that many of his readers will possess little knowledge of how to construct electronic equipment and he therefore places the main emphasis on practical detail, the description of the functioning and performance of the apparatus being necessarily brief.

The book certainly succeeds in its object, in that simple, reliable equipment of fair accuracy can be constructed on the basis of the information supplied. A valuable feature from the point of view of the science master is that some idea of the cost of each instrument is indicated. However, it seems a pity that no detectors other than the Geiger counter are described. Possibly the author feels that other detectors are too complex and costly to be constructed and used in schools.

A. J. L. Collinson.

DILOGARITHMS AND ASSOCIATED FUNCTIONS

By L. Lewin

London : Macdonald and Co. Ltd. Pp. xvi+353. Price 65s.

The series

$$\frac{z}{1}+\frac{z^2}{2}+\frac{z^3}{3}+\ldots$$

convergent for $|z| < 1$, has the sum $-\log(1-z)$. If this is multiplied by $1/z$ and integrated between 0 and z, the new series

$$\frac{z}{1^2}+\frac{z^2}{2^2}+\frac{z^3}{3^2}+\ldots$$

is obtained. This series defines the function first discussed by Euler in 1768 and called the *Dilogarithm* by Hill, in 1828. The present author uses the integral as his definition and writes

$$Li_2(z) = -\int_0^z \frac{\log(1-z)dz}{z}$$

with $-\pi < \arg(1-z) \leqslant \pi$

this definition not being restricted to $|z| \leqslant 1$.

The trilogarithm and higher order functions are then defined by

$$Li_n(z) = \int_0^z \frac{Li_{n-1}(z)dz}{z}$$

This book is concerned with the properties of these and other related functions. They are not of much practical importance, though the author mentions at the end of Chapter I a number of physical problems, including quantum electrodynamics and electrical network problems, in which they have arisen, and in Chapter VIII he discusses their application to integration and summation of series. An example chosen at random is the result

$$\int_0^{\frac{1}{2}\pi} \sin^{-1}(x \sin\varphi)d\varphi = \tfrac{1}{2}Li_2(x) - \tfrac{1}{2}Li_2(-x)$$

The last 100 pages are occupied by a list of formulae and tables of numerical values, without which, of course, results such as the above would be of little practical value.

Although this subject has attracted the attention of many mathematicians, and it has obviously exercised a fascination for the present author, the formulae and relations which arise are in general exceedingly clumsy, and for most people this book will be of interest as a reference book when they are directly concerned with integrals or series which can be evaluated in terms of these functions.

A. W. Gillies

LES ONDES CENTIMÉTRIQUES

By G. Raoult

Paris : Masson et Cie. Pp. vii+401. Price 7,300 fr.

In his book Professor Raoult decided to introduce to the reader the whole field of microwaves in a straightforward and elementary way. This is certainly a vast undertaking and within the self-imposed limits the author succeeds admirably in his task. The price he has to pay for casting his net so widely is a reduction in the amount of detail which it is physically possible to accommodate in some four hundred pages of the text. It is stated in the preface that the main purpose of the book is to encourage and to guide all beginners in their efforts to get acquainted with the physical basis of the microwaves. This attitude requires a careful balance between the intuitive and the mathematical approach, the latter being kept to the minimum. In effect the book should be of interest to all students who have a rudimentary knowledge of physics and working knowledge of elementary calculus.

The book is written largely from the point of view of a physicist. This is refreshing since the field of microwaves has been too long under the sway of engineers. This is not a criticism of engineers, the reviewer being one of their number, but merely an attempt to point out that the book is permeated by a unifying spirit common to all physics. The reader gains the right perspective in the very first chapter and is made to realize that although the actual appearance of microwave apparatus may be strange and novel, the underlying principles of its operation are still the same well known and universal laws of nature. In the following chapters the author explains, very much in physical rather than in mathematical terms, the principles of operation of waveguides and transmission lines (Ch. II–VIII) and of the measuring techniques, including the measurement of impedance (Ch. IV), frequency and power (Ch. VII) and dielectric constant (Ch. IX). Further chapters deal with the generation and amplification (Ch. X) and detection (Ch. XI) of microwaves (here semiconductors and masers are also mentioned). Finally there is a short discussion of

microwave aerials (Ch. XII), optical analogies such as the dielectric lenses (Ch. XIII), radio-astronomy (Ch. XIV) and paramagnetic resonance (Ch. XV). The book ends with an excellent discussion of the mathematical tools required for a full understanding of the text and a full discussion of electrical units. The reviewer was particularly pleased to see a clear discussion of the extension of the j-notation to the case of vectors—a useful method which is frequently used but seldom explained to the beginner. A clear statement of the advantages of the rationalized M.K.S. system of units should be also noted with pleasure. Since the book is highly physical in its whole spirit, it was rather good to see the destruction of one more citadel of obscurantism and prejudice against the M.K.S. system. This is always a welcome sight, even when it happens in some other distant land.

So much for the attractive features of the book. However, in all fairness to the author there are two criticisms of the book which must be made. First of all the price of the book is quite unjustified. If one thinks of some recent publications at £3 or £4 which, due to the wealth of their mathematical formulæ, must have been much more difficult to set up, the price of Fr. 7,300 for this volume is quite inadmissible. The only excuse the publishers may have is presumably a low expectation of the number of copies sold. The other criticism concerns the drawings—their execution and quality of printing. Many drawings are of course quite good, but some are either badly printed (e.g. Figs. II—14 and XI—12) or inaccurate (Figs. II—5 and V—3, where the various lines do not cross where they should, and Figs. XI—14 and XI—15 where the Fermi level in the semiconductor is wrongly placed). In one case (Fig. IV—16) the figure is quite unreadable. This is really just not good enough in a book at that price. Furthermore, why are all the lower-case letters in the displayed expressions in italics, while the upper-case symbols are roman ? This looks very odd and a trifle untidy. Finally, although the author naturally had the right to choose either the TE_{mn} or the H_{mn} notation for the waveguide modes and further, also had the right to introduce TE mn for TE_{mn}, is it really necessary to have on several consecutive pages (pp. 32-37) TE 10, T E 1 0, T.E 1.0 and T.E.1.0. to designate the same mode ? This is just bad type setting and poor proof-reading.

Should this book be recommended to an English speaking reader ? This is a difficult question to answer. The book is probably designed to fill a gap in the French technical literature and it succeeds admirably in this task. Undoubtedly it provides a unifying approach which is quite refreshing, but there are some English texts which perform a similar function. The final choice must remain with the reader—a young student will hardly be able to afford the price, even if he could afford the time to read a book in a language which is not his own—a qualified scientist working in a different field will enjoy the book for many reasons, but still may hesitate to buy it. Thus it seems that due to its very general nature the book must depend in its sales on the domestic market perhaps to a larger extent than is usually the case with scientific publications.

P. A. LINDSAY.

THEORY OF RELATIVITY

By W. Pauli.

London: Pergamon Press Limited. Pp. xiv + 241. Price 35s.

It is evidence of Pauli's genius that this book written thirty-eight years ago, when the author was only twenty-one, should now be published in an English edition. It remains in its original form in order, we are told, " to preserve the character of the book as an historical document." It is an account of the special and the general theories of relativity as they appeared in 1920, to which Pauli has now added thirty pages of notes. These include some more recent experimental evidence, some alternative mathematical proofs, developments like the work of Friedmann and Lemaitre on the cosmological problem, and attempts at unified field theories.

For the specialist it is an interesting volume. It is unfortunate that the English translation does not read more smoothly.

J. TOPPING

THE PRINCIPLES OF ELECTROPHORESIS

By René Audubert and Serge de Mende

London : Hutchinson & Co. (Publishing) Ltd. Pp. viii + 142. Price 25s.

A brief, sound and reasonably priced introduction to the theory and practice of both the classical method of moving boundary electrophoresis and the more recently developed procedures involving the use of supporting media, such as filter paper, should have a wide appeal. Potentially, this translation from the French is " just the thing," but it would need extensive revision, as the present edition is woefully out-of-date, with virtually no reference to work published later than 1954. Considering the rapid growth and development in the field under review, this is a serious fault, all the more regrettable because the book is beautifully printed and illustrated.

R. ASCHAFFENBURG.

COMMERCIAL AND INDUSTRIAL PHOTOGRAPHY

By D. Charles

London: Chapman and Hall Ltd. Pp. xi + 402. Price 52s. 6d.

In recent years, due mainly to the increasing interest in photography, there has been a veritable flood of books coming on to the market dealing with every aspect of the subject. There has remained, however, a real need for a book that can show how small and important is the gap that lies between the study of photography as an art form and photography as a science.

Mr. Charles has written a book which will go a long way to bridging this gap. He has realized that most amateurs, and even some professional photographers, have only sufficient knowledge of the pure mechanics of their subject to be able to take a reasonable photograph and produce a worthwhile print. What many lack is an appreciation of the restricted sphere in which they work due to their limited knowledge and complete dependence on commercially produced apparatus and materials.

Workers in every field of photography will find the book of great value. The author's style is extremely readable, and he has the rare ability to make even the most complicated aspects of photography appear simple. Above all he makes clear to his readers that it is only in their ability to invent new methods and adapt materials and equipment to their own requirements and limitations that they will find a true and deep understanding of their subject.

The book contains many instructional diagrams, an excellent index, and several photographs. The twenty-five chapters are divided into clearly headed sections and the author includes descriptions of many of his own inventions, some of which have not been previously published. Among the subjects discussed are micrography, "3D," copying techniques, science and research together with detailed descriptions of apparatus, materials and basic theory.

R. G. Atterbury.

GUIDE TO THE LITERATURE OF MATHEMATICS AND PHYSICS INCLUDING RELATED WORKS ON ENGINEERING SCIENCE

By Nathan Grier Park III

New York: Dover Publications, Inc. Pp. xviii + 436. Price $2·49.

There is no doubt that Nathan Grier Parke III has done a great service to his fellow men in compiling this extensive guide to the literature of mathematics and physics. In this second edition there are over 5,000 entries. That this is double the number in the first edition, published in 1947, is some indication of the revision which has been necessary. Most of the references are to books, though some are to published papers in scientific journals, where these, through review articles, bibliographies or otherwise, point the way to further reading. Thus, under the heading "Numerical and graphical methods" are references not only to standard books but also to the quarterly journal *Mathematical tables and other aids to computation*. Papers in the *Reviews of Modern Physics* are frequently cited under headings concerning topics in physics.

Considerable care has been taken in the selection and organization of the material, a task in which the author has been helped by some well-qualified friends and assistants. An effort has been made to include some of the Russian literature. The entire list of entries in the first edition was compared with the reference collections at the Library of Congress, John Hopkins University, and the Massachusetts Institute of Technology. There is evidence of similar care in this edition. Detailed author and subject indices make the tracing of references quick and easy.

The first part of the book, which remains unchanged from the first edition, is an introduction to the art of reading and literature searching. In the reviewer's opinion it is likely to prove more interesting to undergraduates, than to the more senior users of the guide to literature. The book is astonishingly cheap for such a mine of information. It is bound in the familiar paper back of the Dover publications. Whether this will stand the thumbing which a book of this kind will receive seems doubtful. It may prove expedient to produce a more strongly bound edition at a slightly higher price. We can sincerely hope that the author will have time and strength to keep his guide up-to-date in these days of rapidly-expanding scientific literature.

J. Crank.

INTRODUCTION TO THE PHYSICS OF MANY-BODY SYSTEMS

By D. ter Haar

London: Interscience Publishers, Ltd. Pp. viii + 127. Price 30s.

This book surveys the methods which have been applied in the discussion of many-body problems in physics. After an introduction in which the basic ideas are reviewed, Part I deals with methods which try to reduce the problem to one of free particles, while Part II gives a more extensive discussion of recent work on collective behaviour theories, particularly that of Tomonaga and its developments. The last four short chapters briefly refer to applications of these theories.

For the specialist who is already acquainted with some part of this field, the book provides a quick survey of the whole ground and he will be able to select from the references, most of which are dated within the last five years, those he wishes to follow up.

To the more general reader, such as the Physics teacher, for whom this is a new field, the book is likely to be disappointing. It is very much a review of methods, and repeatedly the discussion is cut short with a reference to the literature, before it has really got to grips with the physical problem.

The author appears to indicate a scalar product with both dot and bracket as $(\mathbf{k} \,.\, \mathbf{v})$ which seems unnecessary. In things like $(\mathbf{k} \,.\, \mathbf{x} - \xi)$, which occur repeatedly, the bracket would be more correctly placed round the difference, as $\mathbf{k} \,.(\mathbf{x} - \xi)$. Such incorrect symbolism is becoming all too common. The present author is in fact more careful than many, even to putting brackets round the arguments of exponential functions with only occasional omissions, such as $\exp\,(i/\hbar)\,(\mathbf{p} \,.\, \mathbf{x})$, which is intended to be $\exp\,(i\,\mathbf{p} \,.\, \mathbf{x}/\hbar)$.

A. W. Gillies.

EINFUHRUNG IN THEORIE UND ANWENDUNG DER LAPLACE-TRANSFORMATION

By G. Doetsch

Birkhauser verlag, Basel und Stuttgart. Pp. 301. Price 70s.

Professor Gustav Doetsch is well known for his three-volume *Handbuch der Laplace-Transformation*, which was the first, and even now almost the only, comprehensive mathematical treatise on the Laplace Transform. Between this and the many books in which the interest is solely in the application to engineering problems, there is a gap which the present book is intended to bridge. The length is such that a student can reasonably work through it. The mathematics is treated with adequate rigour. It is written as a textbook, working in general from the easy to the more difficult.

After dealing with ordinary differential and difference equations, the complex inversion formula is introduced

and later chapters consider asymptotic behaviour, ordinary differential equations with polynomial coefficients, partial differential equations and integral equations. This book is well written and attractively produced, and can be strongly recommended to any reader who likes a mathematical approach.

Having said this much one might perhaps comment on the difference between the British and the Continental approach, as exemplified in this volume. Here the tendency is to discuss very general cases, and several times the reader is warned, after such solutions, not to deal with particular problems by quoting the general results, but to apply the method from the beginning to the particular case. In the whole section on ordinary differential equations there is only one numerical example, and this is taken from Carslaw and Jaeger. Throughout the book there are no examples for the student to solve, an omission which we should regard as unthinkable in any textbook produced in this country.

A. W. GILLIES.

Branch News

Manchester and District Branch Summer Visit 1959

On the afternoon of Wednesday, July 1, 73 members of the Branch visited the Jodrell Bank Experimental Station of the University of Manchester, by courtesy of the Director, Professor A. C. B. Lovell.

After an introductory talk by Professor Lovell we were shown the 250′ steerable radio telescope and then told, in some detail, about two of the projects for which it is being used. First, its use as a radar instrument was described : the present work concerns the reflection of modulated radio waves from the Moon as a means of long-distance terrestrial communication, following the surprising discovery that the Moon acts as a reflector of small depth. This technique was illustrated by recordings which had been made of messages (voices and snatches of Brahms) which had survived the trip to the Moon and back. We were also shown a high-power klystron to be used in the autumn in an attempt to get reflections from Venus.

The second project described to us was the use of the telescope as a sensitive receiver of radio-frequency emission. Its resolution is sufficient to give useful information about the spatial distribution of emission not only from the centre of our own galaxy but also from our nearest neighbour the Andromeda nebula ; the ease with which it can scan raster-wise makes it much more convenient to use than interferometric methods of achieving the same resolution. Many other radio sources are detected, but in general unresolved, and their positions are being plotted and their intensities measured.

Altogether we had an interesting and pleasant afternoon, thanks to the Jodrell Bank staff and to our kindly Manchester weather.

J. E. GEAKE.

Top picture from left to right: Mr. R. M. Lee, Dr. L. Cohen and Prof. H. Lipson.

Lower picture: A group of members (on extreme left, Dr. P. S. Henry, Mr. W. G. Darvell and Dr. C. J. Brown) with the 250 ft. steerable telescope in the background.

APPLIED PHYSICISTS. Applications are invited for vacancies caused by the extension of the development activities of British Nylon Spinners at their Pontypool headquarters. Those who have not only a good training in physics and, for preference, some postgraduate experience, but also have the desire to use their training and see their energies directed to obviously useful ends, should find the work of unusual interest. The objectives can only be properly pursued in co-operation with the commercial staff and with other industries, and therefore there will be plenty of opportunity for the exercise of personal qualities and for the demonstration of initiative and willingness to accept responsibility. Conditions of employment are attractive and in line with the best available in industry to-day, and the Company's premises are in unexpectedly delightful countryside in a rural area, with good communications providing the best of town, sea and country. Housing presents little real difficulty, and the Company gives considerable assistance to new staff in resettling their families. Applications should be addressed to the Personnel Manager, British Nylon Spinners Limited, Pontypool, Monmouthshire.

NATIONAL COLLEGE OF FOOD TECHNOLOGY

CRANWOOD STREET, CITY ROAD, LONDON, E.C.1

Principal: J. D. Mounfield, M.Sc.Tech., Ph.D., F.R.I.C.

Applications are invited for the post of ASSISTANT LECTURER in the college from Graduates in physics or engineering. Special consideration will be given to applicants with experience in industrial engineering. A new College, now almost completed at Weybridge, Surrey, will come into use in October this year and the candidate appointed will be expected to assist with the development of the courses there. New laboratories will provide facilities for original work.

Salary scale: £813 15s. × £26 5s. to £1,207 10s. The starting salary will be dependent on qualifications and experience. Applications forms (obtainable from the College) should be sent to the Principal as soon as possible.

LIVERPOOL RADIUM INSTITUTE MANAGEMENT COMMITTEE

Applications are invited for the post of PHYSICIST (Senior Grade). Candidates must hold a first or second class honours degree in physics, with, preferably, some years' experience in medical physics. Opportunities for research are available in a wide range of problems. Salary and conditions of service as laid down in P.T.A. circular No. 71 as approved by the Whitley Council. Applications, together with the names of two referees, should be addressed to the Secretary, Liverpool Radium Institute, Management Committee, 1 Myrtle Street, Liverpool, 7, not later than seven days after the appearance of this advertisement.

HIGH VOLTAGE RESEARCH

Graduates in Electrcial Engineering or Physics or holders of the H.N.C. in Electrical Engineering, are required for experimental research on High Voltage Problems in a High Voltage Resarch Laboratory. The work covers a wide range and includes the construction and use of impulse voltage and impulse current generators, high direct voltage generators, and electronic equipment.

Applicants should be able to carry out investigations without close supervision.

Previous works' training and laboratory experience are desirable but not essential.

Applications quoting reference N.13 and giving relevant personal details, qualifications and experience should be sent to:

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METROPOLITAN-VICKERS
ELECTRICAL CO. LTD.
TRAFFORD PARK
MANCHESTER, 17

UNIVERSITY OF NATAL
SOUTH AFRICA

DEPARTMENT OF MATHEMATICS

Applications are invited from suitably qualified persons for appointment to the post of LECTURER IN MATHEMATICS, Pietermaritzburg. The salary scale attached to the post is £1,050 × £60 – £1,530 per annum. The commencing notch on the above salary scale will be dependent on the qualifications and/or experience of the successful candidate. Application forms and further particulars of the post including commencing dates, etc., are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close in South Africa and London on August 15, 1959.

D.S.I.R. Road Research Laboratory, Harmondsworth, Middlesex, requires SCIENTIFIC OFFICERS OR SENIOR SCIENTIFIC OFFICERS, PHYSICISTS to conduct research on (1) rheology of solid-liquid systems and of viscous and visco-elastic fluids to provide basic information for design of bituminous road mixtures, (2) compressibility and strength of soils in relation to design and construction of earthworks for roads (an engineer with an interest in physics would also be acceptable). Work is varied and interesting and carried out both in laboratory and field, providing contacts with other physicists, chemists, engineers and mathematicians in U.K. and abroad. Qualifications: 1st or 2nd class honours degree in physics or equivalent. For Senior Scientific Officer at least three years' postgraduate experience required. Salary: (Men) Scientific Officer £655 – £1,150; Senior Scientific Officer £1,233 – £1,460. Prospects of promotion in mid-thirties to Principal Scientific Officer (£1,500 – £2,120). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1 (quote ref. A.252/9A).

UNIVERSITY OF THE WITWATERSRAND,
JOHANNESBURG, SOUTH AFRICA

Department of Physics, CHAIR OF EXPERIMENTAL PHYSICS. Applications are invited for appointment to the post of Professor of Experimental Physics in the department of physics. Duties are to be assumed on January 1, 1960, or as soon as possible thereafter. The salary attached to the post is on the scale £2,300 × £75 – £2,600 per annum. In addition, it is anticipated that the University will be authorized to pay an annual vacation bonus of £60. Membership of the University Institutions Provident Fund is compulsory. Membership of the Staff Medical Aid Fund is also compulsory in the case of an officer who is eligible for such membership. Applicants are advised to obtain a copy of the information sheet relating to the above vacancy from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in South Africa and London, on August 31, 1959.

PRINTED BY F. J. MILNER AND SONS LIMITED, COMMERCE ROAD, BRENTFORD, MIDDX.

UNIVERSITY OF CAPE TOWN
SOUTH AFRICA

LECTURER IN PHYSICS

Applications are invited for the above post. The salary scale is £1,340 × £60–£1,760 per annum. The duties of the lecturer will include teaching and laboratory supervision of students and some examining and organizing of courses. He will be expected to supervise the use of a modern electron-microscope and should be interested in research on electron diffraction or some branch of physics involving the electron-microscope. Applications (with copies of testimonials) should state age, qualifications, experience and research work completed or in progress and give the names of two referees whom the University may consult. Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and further information about the work of the department should be obtained) not later than September 1, 1959. An additional copy should be sent direct by airmail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date. The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

COURSES

THE POLYTECHNIC,
309 REGENT STREET, W.1.
DEPARTMENT OF MATHEMATICS AND PHYSICS

Full-time and part-time day courses are available for B.Sc.General in pure mathematics, physics and chemistry (Part 1), physics and mathematics or chemistry (Part 2); B.Sc. Special in physics, and Grad.Inst.P. Evening courses are offered in B.Sc. General; statistics; electronics; and postgraduate mathematics. Prospectuses may be obtained from the Director of Education.

SURREY COUNTY COUNCIL
EWELL COUNTY TECHNICAL COLLEGE

A course of 12 weekly lectures on "Transistors and their Applications" will begin on Tuesday, September 22, 1959, at 7.0 p.m. The course will deal with basic semiconductor physics, transistor design and construction, transistor equivalent circuits; circuits using transistors in amplifiers, generators, computers, and power supplies. A knowledge of elementary physics will be assumed. Course fee: £1 2s. 6d. Apply immediately to Head of Science Department, Ewell County Technical College, Ewell, Surrey.

WOOLWICH POLYTECHNIC
DEPARTMENT OF MATHEMATICS

M.Sc. COURSE

Applications are invited from suitably qualified candidates for a one-year full-time course leading to the M.Sc. degree in mathematics. The department offers courses in the subjects (*a*) functions of mathematical physics, (*b*) elliptic functions, (*c*) hydrodynamics, (*d*) electromagnetic theory, (*e*) elasticity and plasticity, of which two must be studied. The department of scientific and industrial research has accepted this course as suitable for the tenure of its advanced course studentships. Applications should be made both for the course and the studentships to the head of the mathematics department as soon as possible.

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